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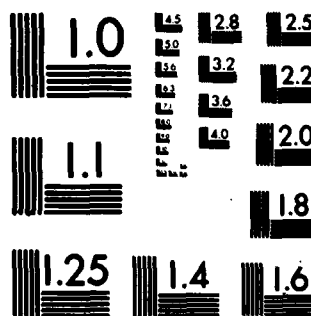
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PERFORMANCE EVALUATION OF POINT-OF-USE WATER HEATERS.(U)
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PERFORMANCE EVALUATION OF
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PERFORMANCE EVALUATION OF POINT-OF-USE WATER HEATERS

This Technical Note provides methods for the selection of point-of-use water heaters to be used as boosters for storage water heaters with lowered temperature settings and to be used as replacement for storage heaters in special circumstances. Point-of-use heaters offer a potential for the significant reduction of water heating energy use in some circumstances. The development of rational methods for selection of new and retrofit water heating systems will permit Facilities Engineers to choose the most energy efficient and/or cost effective of many alternatives which are available.

This Technical Note applies to all Facilities Engineering elements responsible for design, operation, and/or maintenance of energy conservation programs at Army installations.

Point-of-use water heaters are small units designed to serve one or, sometimes, several hot/tepid water taps. They fall into two general categories:

- Analysis of water heating energy use at some typical Army facilities predicted a large potential for the reduction of water heating energy use. The largest energy use reductions were obtained when a point-of-use water installation was combined with faucet flow restrictors and temperature set-back of an existing storage heater. Methods to analyze the conservation potential and life cycle cost of various water heating alternatives have been developed.

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ECONOMICS

Significant energy savings achievable with point-of-use water heaters are usually accompanied by increases in life cycle cost. This apparent contradiction is readily explained by the fact that point-of-use heaters are electrically heated whereas many storage heaters are supplied with lower cost gas or oil fuel. Point-of-use heaters should prove to be cost effective in many cases where existing storage units are electrically heated. The use of point-of-use heaters as boosters for storage units with lowered temperature and combined with faucet flow restrictors presents additional opportunities to reduce both the use and cost of energy.

Methods have been devised to permit analysis and comparison of the energy and cost effectiveness of various alternatives for water heating systems in both retrofit and new construction circumstances at Army facilities. These methods are simple and straightforward requiring only arithmetic calculations to arrive at the most desirable alternative.

GUIDELINES TO IMPLEMENTATION

The steps to be taken in selecting among water heating alternatives for new construction and retrofit are simple and easily followed. The Facilities Engineering Support Agency prepared a report entitled 'Performance Evaluation of Point-of-Use Water Heaters' to assist Facilities Engineers in analyzing and implementing water heating system selection for residential, office, outpost, hospital and other applications. This report contains code and legal references applicable to water heaters. The Appendix contains many examples of how to make energy conservation and life-cycle cost analyses of water heating system installations.

REPORT FESA-TS-2081

PERFORMANCE EVALUATION OF POINT-OF-USE WATER HEATERS

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JOHNS-MANVILLE SALES CORPORATION
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15 OCTOBER 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Point-of-use water heaters are designed to be installed at the location where hot or warm water is used. Thus, such water heaters may be connected to a water faucet, dishwasher, clothes washer, shower or the like. Two types of heaters are available. One is referred to as instantaneous and it has no storage capacity. The second is a very small 1/2 to 6 gallon storage tank type of heater which has nearly negligible standby losses. Point-of-use water heaters offer the greatest potential for energy			

conservation on Army facilities when used as boosters for domestic dishwashers and to replace large storage heaters in buildings where the only requirement for hot or tepid water is in lavatories. A method has been developed to calculate the energy conservation potential of water heaters. The results of this method may be used for life-cycle cost analysis.

SUMMARY

Water heaters have been regarded as wasteful of energy. Studies sponsored by the government have identified the standby heat losses of domestic water heaters as being indeed, very significant.⁽¹⁾⁽²⁾ Buildings having multiple temperature requirements for hot water dictate that a central, storage type of heater be adjusted to meet the hottest of the several temperature requirements. Thus, the water heater in single family housing may be set to 140°F to satisfy a 15 gallon per day dishwashing requirement when 110°F or 120°F would easily suffice for the remaining 60-65 gallons per day of domestic hot water use.

Point-of-use water heaters offer a means for achieving significant energy conservation. These heaters may be used as boosters. For example, they can boost 120°F storage water to 140°F for dishwashers. Point-of-use heaters can also replace storage heaters in offices, schools and the like where only tepid water is required for lavatory basins. Two basic types of point-of-use heaters were disclosed by this study. One type is an in-line resistance heater activated only when water flows and limited in applicability by the power rating, water flow rate and incoming water temperature. This sort of heater may find its widest application as a booster unit for warm or tepid, constant temperature water. The second type of heater employs a small storage tank, 1/2 to 6 or even 10 gallons and is limited by the storage capacity and recovery rate. These heaters appear to be well suited to lavatory use and may be adapted to other uses as well.

Energy savings and life-cycle costing analyses have been made for the various types of heaters under several different circumstances. Energy savings were very great in most cases. However, annual energy cost increased in many cases, because of the point-of-use heaters being electrically heated. Life cycle costs showed that point-of-use heaters can be cost effective in some circumstances. Calculations should be made for each different application being considered because the life cycle cost is influenced by installed price, delivered prices of the energy sources involved, and present worth factors for different energy sources in different regions.

The installations of point-of-use heaters as boosters for storage heaters combined with the installation of flow restrictors on faucets represents one situation which is likely to offer significant energy and cost savings.

The energy and cost analyses clearly illustrated that each potential application of water heaters must be calculated using current and local data. Selling prices of point-of-use heaters may vary over 100 percent for a given make and model due to multiple discount schedules and direct sales to some purchasers.

Two interesting alternatives were disclosed during this study.

- Retrofit insulation of existing storage water heaters is a very cost effective means to achieve energy savings.
- There are several domestic dishwashers on the market having built-in heaters which raise the temperature of first and last fills to 140°F. Purchase of these brands and models would eliminate the applicability of point-of-use booster heaters while permitting a 110°-120°F storage water heater setting in residences.

This report provides sample calculations for comparing energy use and costs of water heating alternatives in different types of buildings and for both retrofit and new construction. Pertinent building, fire and electrical code references are also given.

TABLE OF CONTENTS

SUMMARY	<u>Page</u> 1
PREFACE	4
INTRODUCTION	4
LITERATURE SURVEY	7
MARKET SURVEY	8
Method	8
Survey of Manufacturers	8
Safety, Legal and Code Requirements	19
EVALUATION OF HOT WATER USE IN ARMY FACILITIES	21
WATER HEATING ENERGY USE AND OPERATING COSTS	39
General Considerations	39
Comparison of Standby Water Heaters to Point-Of- Use Water Heaters	50
How to Select Point-Of-Use Water Heaters	51
CONCLUSIONS	55
RECOMMENDATIONS	56
REFERENCES	57
APPENDIX	
Energy Calculations and Life Cycle Cost Analyses	59

PREFACE

Dr. P. L. Earle, Consultant, provided market research assistance and inputs for the energy analysis segments.

Mr. R. H. Neisel, Senior Research Associate, was a valuable resource in the areas of building codes and heat losses from transmission pipes.

Additional, valuable information was obtained through interviews with the following persons or agencies.

Susanne Schermerhorn, OSHA, Denver, Colorado.

J. Hayes, Chief of Utilities, Fort Rucker, Alabama.

R. Wynn, Fort Rucker, Alabama.

D. Brown and J. Moore, Key Energy Systems, Tampa, Florida.

Boyd Distributing, Denver, Colorado.

Solaron, Inc., Denver, Colorado.

INTRODUCTION

Point-of-use water heaters in residential and light commercial applications may be of two types -- instantaneous and semi-instantaneous.⁽³⁾ The instantaneous type is usually electrically heated and transmits energy to water flowing through the unit to provide a temperature rise in the service water which is dependent on the incoming service water temperature, the water flow rate through the unit, the power consumption of the unit and the efficiency of the unit. The semi-instantaneous water heater is usually a very small version of a typical residential water heater (referred to in this report as a mini-tank) and may have a storage capacity in the range of one gallon (lavatory faucet) to fifteen gallons (food service facility). The service water temperature from semi-instantaneous units is often thermostatically controlled thus providing year round temperature uniformity independent of flow rate and temperature of incoming water.

The economical benefit claimed for point-of-use water heaters is reduction of energy use. Conservation may be achieved through one or more of the following:

- Reduce water storage temperature in existing heaters by using the point-of-use device as a booster heater.
- Reduce standby losses from existing heaters.
- Reduce standby losses from distribution piping.
- Eliminate, in some instances, the need for storage water heaters and hot water distribution lines.

A second benefit claimed for point-of-use water heaters is the potential to eliminate the risk of scalding burns from lavatory faucets. This risk may be present wherever it is necessary to maintain water storage over 120°-125°F as may be indicated for dishwashing, laundry use and sanitizing. Point-of-use heaters may be installed to serve only the appliances requiring hot water over 120°F and the storage water temperature may be reduced to a safe, personal use level in the range of 105°F to 120°F.

A third, and potentially minor, claimed benefit is reduction of scale formation in hot water pipes.

There are many potential applications for point-of-use water heaters at Army installations. These applications include:

Single Family Housing

Dishwasher booster

Eliminate storage heater and install on all taps

Offices

Lavatories

Possibly showers if these facilities available

Training Centers

Lavatories

Mess Halls, Clubs

Dishwasher booster

Beverage preparation

Maintenance Facilities
Lavatories

Laboratories
Lavatories
Glassware washers
Sinks

Hospitals
Many potential applications as illustrated above
Specialty baths
Remote Outposts
Lavatories

Barracks
Lavatories
Showers

Schools
Lavatories
Laboratories
Showers (Possibly)

Evaluation of the potential energy conserving benefits offered by point-of-use water heaters can be made from just a few data points. The required data include:

- incoming water temperature
- water flow rate
- required service water temperature
- estimated service cost and standby losses for existing system

The comparative analysis may be made for each individual tap being considered. Some general guidelines will, however, serve to guide the study to the most promising opportunities without the need for a "faucet-by-faucet" study. This report will guide the reader to these best opportunities. An excellent source of supplemental information is contained in Chapter 37 of the ASHRAE Handbook, 1976 Systems.

There are additional factors beyond energy conservation to consider when studying the possible installation of point-of-use water heaters as temperature boosters or as replacements. These factors include:

- Underwriters Laboratories label service for electric units.
- Compliance with National Fire Protection Agency's National Electric Code.
- Compliance with National Sanitation Foundation requirements.
- Potential applicability of local building codes.
- Cost effectiveness of the unit being considered using DoE Life Cycle Costing methods

There may, of course, be additional local considerations such as the availability of money to accomplish hot water system retrofit and renovation work.

This report will provide guidance in all these areas pertinent to the selection of the most energy efficient use of point-of-use hot water heaters. The report consists of a Literature Survey, Market Survey (includes codes and regulations), Evaluation of Hot Water Use in Army Facilities, and Analysis of Energy Use and Operating Costs. Conclusions and Recommendations have been offered. Appendix A contains detailed examples of Life Cycle Cost Analyses of a point-of-use hot water heater.

LITERATURE SURVEY

The literature survey was conducted by Ms. Suzanne D.A. Graham who is on the Corporate Information Center staff of the Johns-Manville Research & Development Center. The principle resources were computer-based searches. The major sources which were reviewed included:

NTIS - National Technical Information Service
U.S. Department of Commerce, Springfield, Virginia

Engineering Index

Applied Science and Technology Index

Abstracts for over 400 water heater references were reviewed and less than a dozen pertinent references were revealed. The bulk of the references pertained to solar water heating. Several newspaper and newsstand magazine references were also found but these seemed to be of the "publicity" type of reference concerned with only one brand of point-of-use heater. The ASHRAE Handbooks were the most productive information sources and are referenced throughout this report. No bibliography has been provided as the Reference Section includes all of the useful documentation found in the literature search.

MARKET SURVEY

Method

The market survey was intended to identify manufacturers of appropriate water heating devices; seek out the operating characteristics and benefits of the various units; obtain warranty details; and identify safety, legal and code requirements relating to typical residential and light commercial water heating devices. The following actions were taken to achieve the objectives of the market survey:

- Letter to manufacturers.
- Interviews with manufacturers, an energy consultant, a code consultant and Facilities Engineering personnel.
- Review of National Building and Mechanical Codes, National Fire Code, and Underwriters' Laboratories Procedures.

Survey of Manufacturers

The letter sent to water heater manufacturers is reproduced on the following page. The source of manufacturers solicited was the Thomas Register⁽⁵⁾ and all firms listed under the categories of instantaneous hot water heaters and water heaters were solicited. Approximately 350 inquiries were mailed and the responses numbered 45. The responses were from

manufacturers and this is considered very good because many of the firms on the mailing list were distributors and/or dealers. The 45 replies were cataloged according to their applicability as follows.

**Johns-Manville
Sales Corporation**

Research & Development Center

Ken-Caryl Ranch
Denver, Colorado 80217
(303) 979-1000

October 25, 1979

Dear Sir:

Johns-Manville R&D Center is conducting a contract study of point-of-use and instantaneous hot water heaters. Our client is most interested in learning the circumstances under which these types of heaters may be of economic benefit; especially, but not exclusively, in retrofit or add-on circumstances.

Would you please send me copies of your advertising and technical literature. I would also appreciate your assistance in providing mathematical models or algorithms which are designed for use in selecting among various types of hot water heating units for residential, remote service, and multiple occupancy buildings. Examples of life-cycle costing for point-of-use and instantaneous units would be most helpful.

Yours truly,


P. B. Shepherd

Respondents with appropriate equipment for direct,
residential and lavatory installation:

W. L. Jackson Manufacturing Co., Inc.
P.O. Box 11168
Chatanooga, Tennessee 37401
- Small (6-20 gal) tanks, 1500 watt heater, no catalog
or prices submitted.

Waage Electric, Inc.
820 Colfax Avenue
Kenilworth, New Jersey 07033
- 2.6-4.5 gal storage, 40-190GPH depending on temperature.

Chronomite Laboratories Inc.
21011 South Figuerora
Carson, California 90745
- 2300-9000 watts, UL listed, special units available.

Consolidated Imports, Ltd.
1121 Grant Street
Denver, Colorado 80203
- Zanker Forbach Minitherm German unit 6 kW
and 1 gpm flow, \$169 cost.

Ruud Water Heater Division
City Investing Company
7600 S. Kedgie Avenue
Chicago, Illinois 60652
- 6-17 gal, 2000 watt, UL approved

Key Energy Systems Inc.
P.O. Box 18264
Tampa, Florida 33679
- Requires 240 volts, UL approved, NEC, NFPA 10, 15 and
20 kW units, recommend low flow rates,
list price range \$280-330.

In-Sink-Erator Division
Emerson Electric Company
Racine, Wisconsin 53406

The Electric Heater Company

P.O. Box 288

45 Seymour Street

Stratford, Connecticut 06497

- One gallon tank, 1000 watts, thermostat control, high limit safety. \$152 list price.

Respondents with commercial equipment which might be suitable for residential use:

Industrial Engineering & Equipment Company

425 Hanley Industrial Court

St. Louis, Missouri 63144

- Series 355 instantaneous water heaters; 1 to 36 kW in single stage units.
\$400-1120, 110 lb - 300 lb, includes thermostat; various monitoring configurations available also gas fired units start at \$1460 for 5 kW unit; also offer booster heaters for commercial dishwashers.

Emerson Electric Company

7500 Thomas Blvd.

Pittsburgh, Pennsylvania 15208

- Chromalox circulation heaters, UL listed 1500-1800 watts, replaceable elements, thermostat.

Respondents with commercial equipment which might be adapted for residential use:

ITT Vulcan Electric

Kezar Falls, Maine 04047

Graham Manufacturing Company

170 Great Neck Road

Great Neck, New York 11021

- Graham Heliflow Hot Water Heater.

McGraw-Edison Company

Old Highway 36

Clarence, Missouri 63437

- Tubular heater, circulation heater.

Respondents with commercial/industrial equipment which was oversized according to the scope of this study:

Leslie Company
Parsippany, New Jersey 07054

Mel Sears & Company, Inc.
Holland Patent, New York 13354

Robertshaw Controls Company
Knoxville, Tennessee 37901

Respondents whose products did not fit the scope and objective of this study:

Taco Inc.
Cranston, Rhode Island 02920

Reimers Electra Steam Inc.
Clearbrook, Virginia 22624

Ace Buehler Inc.
Orange, California 92668

The Johnson Corp.
Three Rivers, Missouri 49093

Amtrol Inc.
West Warwick, Rhode Island 02893

The Alstrom Corp.
Bronx, New York 10461

Dormont Manufacturing Company
Pittsburgh, Pennsylvania 15201

Kitchen Aid Dishwasher Division
The Hobart Manufacturing Company
Troy, Ohio 45373

Sen-Dure Products, Inc.
Bay Shore, New York 11706

Hotwatt Inc.
Danvers, Massachusetts 01923

Helcodyne, Inc.
Richmond, California 94804

Weber Industries Inc.
Dallas, Texas 75235

J.J. Finnigan Industries Inc.
Duluth, Georgia 30136

Rama Corp.
San Jacinto, California 92383

Quiet Automatic Water Heater Corp.
Newark, New Jersey 07104

Infern-O-Therm Corp.
Keyport, New Jersey 07735

George Ulamet Company
Newark, New Jersey 07105

Tempco Electric Heater Corp.
Schiller Park, Illinois 60176

Federal Boiler Company
Fairfield, New Jersey

Sylvania Lighting Products Corp.
Exeter, New Hampshire 03833

A. O. Smith
Kankakee, Illinois 60901

Way-Wolf Associates
Long Island City, New York 11101

Sioux Corporation
Buresford, South Dakota 57004

The Carlin Company
Weathersfield, Connecticut 06190

Ewing Manufacturing Company
Oklahoma City, Oklahoma

Ametek
Cornwells Heights, Pennsylvania 19020

New Yorker Steel Boiler Company Inc.
Colmar, Pennsylvania 18915

Techne, Inc.
Princeton, New Jersey 08540

General Fittings Company
Manasquan, New Jersey

This report will be limited to those heaters which are directly applicable to residential and light commercial use. The guidelines offered in Appendix A may also be applied to other types of heaters which might be offered for use in special circumstances. There are three different types of light duty, point-of-use water heaters.

1. In-line, resistance heaters. This type of heater is available from:

- Key Energy Systems called Hot Line.
- Consolidated Imports called Minitherm.
- Chronomite Laboratories Inc. called Instant-Flow.

All of the units are small and can be conveniently mounted under a sink or near a dishwasher. They operate by electrical resistance heating of the water as it passes through the unit. The Hot Line was available in three sizes, 10, 15, and 20 kW. Each required 240 volt service and was available single or three phase.

The Minitherm unit was advertised as being available only in one size. It was rated at 6 kW and 1 gallon per minute flow rate. Required service voltage is 208/277 and the model designation is MDT 6000.

Chronomite offers seven stock units ranging from 2.3 kW to 9.0 kW. The 2.3 and 3.0 kW units are available for 110 or 220 volt electrical service. The higher kW units are for use

with 220 volt electrical service only. Special models of 1.0 to 9.0 kW and 110 to 250 volts are also offered.

All instantaneous electrical resistance water heaters represented by the above three brands will provide a fixed temperature rise which is a function of flow rate and kW output. Thus, the water they provide will fluctuate in temperature as the temperature of the incoming service water varies. Such units may, therefore, find their most useful application as booster heaters to be used in conjunction with a controlled warm water source. A good example of this would be in a residential water supply. The central water heater could be set down to 110°F-120°F which should be adequate for showers, baths, and general personal use. An instantaneous point-of-use heater could then be used to provide 140°F-160°F water required for dishwashing. It is important to select the proper kW rated heater to match the supply water temperature and flow rate for the desired outlet water temperature. Guidelines for making this simple calculation are in Appendix A. For example, a 10 kW unit would be needed to boost 105°F water to 140°F at 2 gpm. If a 6 kW unit were installed, the water flow to the dishwasher would have to be restricted to about one gallon per minute. And, if electric supply were limited to 110 volts it would be necessary to reduce water flow to 1/2 gallon per minute and use a 3 kW unit. Manufacturers' literature may not provide the best guidance in selecting the proper unit. For example, flow rate tables supplied by Chronomite are quite different from ASHRAE guidelines(6) and could lead to selection of an underpowered unit unless, of course, a calibrated flow restrictor were to be installed along with the heater.

There is an alternate approach to booster heaters for dishwasher service. This was not within the scope of this study, but should be mentioned as a likely economical alternative. Kitchen-Aid by Hobart has introduced a home dishwasher, model KD-19, with a built-in 700 watt water heater. This heater boosts water temperature for the first and last fills to over 140°F. The Kitchen-Aid function and concept is not new but it is the first time built-in heaters have been promoted for energy conservation. Other brands and models of dishwashers, current and old, may offer the same function but have not disclosed it as an energy saving booster heater. For example, some Whirlpool models have a "Super Scour" cycle which seems to function just like the new Kitchen-Aid. A 750

watt immersion heater boosts first and last fill temperatures to over 140°F when the "Super Scour" cycle is selected.

2. Mini-storage tank heaters. These units are available from:

- In-Sink-Erator Division called Ultra Warm.
- The Electric Heater Company called Hubbell.

The expression, "mini-storage tank heaters" was adopted by the author to distinguish these less-than-2 gallon heaters from larger, more conventional point-of-use storage heaters.

The In-Sink-Erator unit is a unique device called the Ultra Warm System. A 750 watt heater is contained in a 1/2 gallon tank. The 190°F water is automatically mixed with cold water in a special faucet which must be installed as part of the system. This faucet then provides either cold or warm water at the users' selection. The unit plugs into a 110 volt electrical outlet. The Ultra Warm is suitable for lavatory use only because of the special faucet. A companion unit called Ultra Hot has a separate push button which permits dispensing, only 190°F water for the preparation of beverages, soups and instant foods. A "Special" model of the Ultra Warm is offered with a 1300 watt heater which will provide 10.8 gallons per hour of warm water compared to the 6.25 gallons per hour from the 750 watt standard model. All units are equipped with an adjustable thermostat.

The Electric Heater Company Model CE-110 is a one gallon tank with a 1000 watt electric heater. Heaters of different wattage will be supplied on special order. An adjustable thermostat is supplied. Electrical service required is 120 volts. The unit is designed to be operated at 150°F-155°F and the hot water mixed with cold through a conventional tempering valve so that supply warm water can be regulated to any desired temperature. This unit also appears best suited to lavatory installation. However, installation of a larger heating element which has been special ordered, could match the units' output to a residential dishwasher requiring 140°F or hotter water. The CE-110 equipped with a properly sized heating element could also be used as a booster heater for warm, 110°F, supply water. The electric supply could be

connected to a switch so that the unit is turned on only shortly prior to dishwasher use. This would eliminate the small standby losses which might otherwise be experienced.

3. Storage Point-Of-Use Heaters. Any storage tank water heater which is located adjacent to the faucet or appliance it serves is technically a "point-of-use" water heater. This may then be a 2-1/2 gallon tank installed under the wash-up sink at the Fort Rucker Motor Pool, or a pair of 18 gallon booster units providing the required 180°F water to a large commercial dishwasher in a mess hall. Small, under-sink heaters and boosters are available from:

- Waage Electric Incorporated,
- W.L. Jackson Manufacturing Company,
- Rudd Water Heating Division

The units sold by Waage are designed as commercial dishwasher boosters and are available in sizes up to 18 gallons with a 60 kW heater. Their smallest unit, however, is 2.6 gallons with a 6 kW heater. The unit is equipped with a thermostat and could easily function as a lavatory point-of-use heater, a residential dishwasher heater or booster, or a small commercial dishwasher booster.

The Jackson Company provided no literature or technical information except to state in a letter that their 6, 12, and 20 gallon units would fit under a sink and that each contained a 1.5 kW heater for either 120 or 240 volts.

The point-of-use heaters offered by Rudd are, like those described by the Jackson Company, small, electrically heated tanks. The sizes offered are 6, 10, 15, 17, 20 and 30 gallons. The standard heating element is 2.0 kW for 120 volt service. A 6.0 kW heater is available at higher voltages of 208, 240, 277, and 480.

Warranty

A brief description of the warranty or guarantee offered by each of the manufacturers who replied to the survey follows.

Key Energy Systems-Hot Line

Unit carries a three year conditional warranty. No details were provided.

Consolidated Imports-Minitherm

There was no reference to a warranty.

Chronomite Laboratories Instant-Flow

Guaranteed to be free from defects in material and workmanship for one year. Inspection and repair or replacement must be done at factory.

In-Sink-Erator Division-Ultra Warm

Warranted for one year to be free from manufacturing defects in workmanship and material.

Electric Heater Company - Hubbell CE-110

No reference to a warranty was provided.

Waage Electric Inc.

Guaranteed for one year or 1000 hours continuous operation against electrical or mechanical defects. Defective parts replaced when returned to factory.

W.L. Jackson Manufacturing Company

No reference to a warranty was provided.

Rudd Water Heater Division

Warranty against factory defects in material and workmanship set forth in considerable detail. The tank is warranted for five years and other parts are warranted for one year. Specific disclaimers are listed. Provides for claim service by local suppliers.

Safety, Legal and Code Requirements

There are a number of requirements relating to safe operation, and code regulations for water heaters. These requirements vary according to heat source (electric, gas, oil, steam), operating pressure and size. All of the point-of-use

water heaters pertinent to this study were small, electrically heated units so that only the requirements relating to these units will be presented.

The basic document appears to be the National Electric Code as published by the National Fire Protection Association. This states that electric water heaters shall have a temperature limiting means plus a control thermostat. And, water heaters shall be marked to require the installation of a temperature and pressure relief valve. An exception is granted for heaters having a capacity of one gallon or less which are "approved for the purpose". The code does not state how water heaters may qualify for the exception by being "approved for the purpose". The heater cord shall comply with certain stated requirements. Also, in Section 89M, NFPA requires a one inch minimum clearance from combustible surfaces and states that water heaters shall not be installed in alcoves or closets. This is not a mandatory requirement for residential installations. (7)

Underwriter Laboratories (UL) provides a listing service for approved water heaters. The UL listing approval can be readily determined as each appliance must bear the UL listing mark. No heater should be purchased without the UL mark on the appliance.

The principle building/mechanical codes have requirements relating to water heater installations. Local building inspectors may have slightly different requirements. It is likely that any heater with a UL listing mark which is to be installed in accordance with the National Electric Code will be acceptable. Check with the building/mechanical inspector in circumstances where local codes will apply.

The following manufacturers in the survey are shown as having listed water heater appliances in the May 1979 Electrical Appliance and Utilization Equipment Directory of Underwriters Laboratories.

Chronomite Laboratories
In-Sink-Erator Division
Electric Heater Company
Jackson Manufacturing Company
Waage Electric Inc.
Rudd Company

Consolidated Imports and Key Energy were not shown but may appear in later editions. Chronomite Laboratories, while listed, stated in their literature that the purchaser must specify the UL label on the order for each appliance.

The National Sanitation Foundation has regulations relating to water temperature and pressure for commercial dishwashers.

OSHA 2206 Safety and Health Standards states in 1910.141 (d)(2)(ii) that lavatories shall be provided with hot and cold running water, or tepid running water. Temperature limits for "hot", "cold", and "tepid" are not provided. ANSI Standard Z4.1 which was the source document for 1910.141 also does not provide definitions of hot, cold or tepid. Tepid is usually defined as warm to touch. This is a very subjective specification for water temperature in offices, outposts, and other buildings having only lavatory facilities. A water temperature of 95°F-105°F should, therefore, be sufficient. If showers are provided in a building, point-of-use water heaters may not offer a potential energy savings.

Finally, ASHRAE has suggested that a thermostatic mixing valve should be used to maintain a uniform temperature of hot water supply to the plumbing fixture to prevent danger of scalding.⁽⁸⁾

EVALUATION OF HOT WATER USE IN ARMY FACILITIES

Hot water use at Army facilities was surveyed through literature references^(9,10,11) and observations at Fort Rucker, Alabama. The types of buildings and their use sources of hot water which were considered include:

- | | |
|-------------------------|------------------|
| Single Family Residence | - lavatory |
| | - shower |
| | - dishwasher |
| | - clothes washer |
| Barracks | - lavatory |
| | - shower |
| | - janitorial |
| Office | - lavatory |
| | - janitorial |

Outposts	- lavatory
Base Exchanges (without kitchen or cafeteria)	- lavatory - janitorial
Food Service Facilities	- dish rinsing - dishwasher - lavatory - janitorial
Hospitals	- operating rooms - out-patient rooms - showers - lavatories - laboratories - janitorial
Schools	
Elementary	- lavatory - janitorial
Secondary	- lavatory - showers - laboratory - janitorial
Libraries	- lavatory - janitorial
Mechanical Service Stations	- lavatory - shower
Training Facilities	- lavatory - janitorial

Point-of-use water heaters and especially instantaneous heaters are usually of limited capacity so that it is necessary to identify the hot water requirements of each point of service. There is much contradiction in the literature on this subject. This is best illustrated by the article, "It Can Be Confusing",⁽¹²⁾ which concluded that there are differences in hot water use which may vary, for example, by geographical area. It is mandatory for this study that representative hot water use figures be selected for the calculations and for decisions.

The data used were taken predominately from ASHRAE Design guidelines and are shown in Tables 1 through 8.

TABLE 1

FIXTURE HOT WATER FLOW RATES (13)

<u>Fixture</u>	<u>Gallons Per Minute of Hot Water</u>
Lavatory Faucet	2.25
Sink Faucet	3.38
Bathtub Faucet	4.50
Laundry Sink	3.75
Shower	2.75 - 7.50

TABLE 2

HOT WATER DEMAND FOR VARIOUS TYPES OF BUILDINGS⁽¹⁴⁾

Gallons of Water Per Hour Per Fixture, Calculated at a Final Temperature of 140°F

	<u>Club</u>	<u>Gymnasium</u>	<u>Hospital</u>	<u>Industrial Plant</u>	<u>Office Building</u>	<u>Private Residence</u>	<u>School</u>
Basins, private lavatory	2	2	2	2	2	2	2
Basins, public lavatory	6	8	6	12	6	-	15
Bathtubs	20	30	20	-	-	20	-
Dishwasher	50-150	-	50-150	20-100	-	15	20-100
Foot Basins	3	12	3	12	-	3	3
Kitchen Sink	20	-	20	20	20	10	20
Laundry, stationary tubs	28	-	28	-	-	20	-
Pantry sink	10	-	10	-	10	5	10
Showers	150	225	75	225	30	30	225
Slop sink	20	-	20	20	20	15	20
Hydrotherapeutic Showers	-	-	400	-	-	-	-
Hubbard baths	-	-	600	-	-	-	-
Leg baths	-	-	100	-	-	-	-
Arm baths	-	-	35	-	-	-	-
Sitz baths	-	-	30	-	-	-	-
Continuous-flow baths	-	-	165	-	-	-	-
Circular wash sinks	-	-	20	30	20	-	30
Semicircular wash sinks	-	-	10	15	10	-	15

TABLE 3

HOT WATER REQUIREMENT FOR MESS KITCHENS ⁽¹⁵⁾

<u>Equipment</u>	<u>Gal/Hr.</u>
Vegetable sink	45
Single pot sink	30
Double pot sink	60
Triple pot sink	90
Prescrapper (open type)	180
Preflush (hand operated)	45
Preflush (closed type)	240
Recirculating preflush	40
Bar sink	30
Lavatories (each)	5

TABLE 4

RESIDENTIAL HOT WATER USAGE (16)

Food Preparation	3 Gal.
Hand Dishwashing	4 Gal.
Automatic Dishwasher	15 Gal.
Clothes Washer	21 Gal.
Shower or Bath	15 Gal.
Face and Hand Washing	2 Gal.

TABLE 5
HOT WATER DEMANDS AND USE FOR VARIOUS TYPES OF BUILDINGS ⁽¹⁷⁾

<u>Type of Building</u>	<u>Maximum Hour</u>	<u>Maximum Day</u>	<u>Average Day</u>
Men's Dormitories	3.8 Gal/Person	22.0 Gal/Person	13.1 Gal/Person
Women's Dormitories	5.0 Gal/Person	26.5 Gal/Person	12.3 Gal/Person
Office Buildings	0.4 Gal/Person	2.0 Gal/Person	1.0 Gal/Person
Food Service Establishments:			
Full Meal Restaurants and Cafeterias	1.5 Gal/Max Meals/Hr	11.0 Gal/Max Meals/Hr	2.4 Gal/Avg Meals/Day*
Elementary Schools	0.6 Gal/Student	1.5 Gal/Student	0.6 Gal/Student*
Junior and Senior High Schools	1.0 Gal/Student	3.6 Gal/Student	1.8 Gal/Student*

* Per day of operation.

TABLE 6

NSF RINSE WATER (180°F) REQUIREMENTS FOR DISHWASHING MACHINES ⁽¹⁸⁾

<u>Type and Size of Dishwasher</u>	<u>Flow Rate, gpm</u>	<u>Hot Water Requirements, Gal/Hr at 180°F</u>	
		<u>Heaters With No Internal Storage</u>	<u>Heaters With Internal Storage to Meet gpm Flow Demand</u>
Door type			
16 x 16 in. rack	6.94	416	69
18 x 18 in. rack	8.67	520	87
20 x 20 in. rack	10.4	624	104
Undercounter type	5	300	70
Conveyor type single tank	6.94	416	416
Multiple tank (dishes flat)	5.78	347	347
Multiple tank (dishes inclined)	4.62	277	277
Silver washers	7	420	45
Utensil washers	8	480	75
Makup water requirements	2.31	139	139

TABLE 7

HUD-FHA MINIMUM WATER HEATER CAPACITIES
FOR ONE AND TWO FAMILY LIVING UNITS⁽¹⁹⁾

Number of Baths		1-1.5			2-2.5				3-3.5			
Number of Bedrooms	1	2	3	2	3	4	5	3	4	5	6	
GAS^d												
Storage - Gal	20	30	30	30	40	40	50	40	50	50	50	
1,000 Btu Input	27	36	36	36	36	38	47	38	38	47	50	
1-Hr Draw - Gal	43	60	60	60	70	72	90	72	82	90	92	
Recovery - Gal/Hr	23	30	30	30	30	32	40	32	32	40	42	
ELECTRIC^d												
Storage - Gal	20	30	40	40	50	50	66	50	66	66	80	
Kilowatts - Input	2.5	3.5	3.4	4.5	4.5	5.5	5.5	5.5	5.5	5.5	5.5	
1-Hr Draw - Gal	30	44	58	58	72	72	88	72	88	88	102	
Recovery - Gal/Hr	10	14	18	18	22	22	22	22	22	22	22	
OIL^d												
Storage - Gal	30	30	30	30	30	30	30	30	30	30	40	
1,000 Btu Input	70	70	70	70	70	70	70	70	70	70	70	
1-Hr Draw - Gal	89	89	89	89	89	89	89	89	89	89	89	
Recovery - Gal/Hr	59	59	59	59	59	59	59	59	59	59	59	
TANK TYPE INDIRECT^{a,e}												
1-W-H Rated Gal in 3 Hr. 100 F deg Rise		40	40		66	66 ^c	66	66	66	66	66	
Manufacturer Rated Gal 3 Hr 100 F deg Rise		49	49		75	75 ^c	75	75	75	75	75	
Tank Capacity in Gal		66	66		66	66 ^c	82	66	82	82	82	
TANKLESS TYPE INDIRECT^{b,e}												
1-W-H Rated GPM 100 F deg Rise		2.75	2.75		3.25	3.25 ^c	3.75	3.25	3.75	3.75	3.75	
Manufacturer Rated Draw 5 Min 100 F Deg Rise		15	15		25	25 ^c	35	25	35	35	35	

^aBoiler-connected water heater capacities (180 F boiler water, internal or external connection).

^bBoiler-connected heater capacities (200 F boiler water, internal or external connection).

^cAlso for 1-1.5 baths & 4 B.R. for indirect water heaters.

^dStorage capacity, input and recovery requirements indicated in the table are typical and may vary with each individual manufacturer. Any combination of these requirements to produce the stated 1-hr draw will be satisfactory.

^eHeater capacities and inputs are minimum allowable. Variations in tank size are permitted when recovery is based on 4 gph/hr @ 100 F deg rise for electrical A.G.A. recovery ratings for gas heaters, and IBR ratings for steam and hot water heaters.

TABLE 8

REPRESENTATIVE HOT WATER USE TEMPERATURES (20)

<u>Use</u>	<u>Temp.F</u>
Lavatory	105
Showers and tubs	110
Therapeutic Baths	110
Commercial and Institutional Dishwashing	
Wash	140
Sanitizing Rinse	180
Commercial and Institutional Laundry	180
Residential Dishwashing	140
Surgical Scrubbing	110

Additional references used in estimating hot water use are shown in Tables 9 through 12.

TABLE 9

HOT WATER USE AT SOME ARMY FACILITIES (21)

Offices (no kitchen or shower)	2 to 3 gal/day/person
Base Exchange (no kitchen)	1 gal/day/customer
Food Service	3 gal/meal plus 3 gal/day/employee
Schools (including cafeteria and showers)	3 gal/day/person
Barracks	20-30 gal/day/person
Hospitals	30-50 gal/day/person

The data contained in Tables 1 through 9 were used to derive Table 10. This shows the fixture flow rates and demands used in engineering calculations.

TABLE 10

ESTIMATED HOT WATER USE FOR VARIOUS TYPES OF ARMY FACILITIES

<u>Building Type</u>	<u>Fixture</u>	<u>Flow Rate Per Fixture</u>	<u>Use Gal. Per Hour Per Fixture</u>	<u>Temperature °F</u>
Single Family Residence	Lavatory	2-1/4	2	105
	Shower/Tub	3/4-1/2	30/20	110
	Dishwasher	3	15	140
	Clothes Washer	3	20	Tepid (a)
Barracks	Lavatory	2-1/4	8	Tepid
	Shower	3	30	110
	Janitorial	3-3/4	20	Tepid
Office, Library, Training Station	Lavatory	2-1/4	6	Tepid
	Janitorial	3-3/4	20	Tepid
Outpost	Lavatory	2-1/4	2	Tepid
Food Service	Sink (Typical Single)	3-3/4	35	110
	Dishwasher	Varies	Varies	140/190
	Lavatory	2-1/4	5	Tepid
	Janitorial	3-3/4	20	Tepid
Hospital	Sink (Typical)	3-3/4	30	110
	Shower/Tub	6	75/20	110
	Therapeutic Shower (Typical)	?	400	110
	Therapeutic Bath (Typical)	?	100	110
	Lavatory	2-1/4	6	Tepid
	Janitorial	3-3/4	20	Tepid
Elementary School	Lavatory	2-1/4	15	Tepid
	Janitorial	3-3/4	20	Tepid
Secondary School	Lavatory	2-1/4	15	Tepid
	Shower	4	225	110
	Laboratory	3-3/4	30	120
	Janitorial	3-3/4	20	Tepid
Mechanical Service	Lavatory	2-1/4	8	Tepid
	Shower	4	75	110

(a) Use cold water laundry detergent

Manufacturers of two instantaneous, point-of-use heaters also provided some data on hot water fixture flow rates.

Their data are compared with published design data in Tables 11 and 12.

TABLE 11

RATE OF HOT WATER FLOW PER FIXTURE UNIT

<u>Fixture Unit</u>	<u>ASHRAE Design Data</u> (22)	<u>Chronomite Labs Advertising Data</u>
Lavatory	2.25	1
Bath	4.50	1-1/2
Shower	2.75-7.50	2
Washing Machine	3.75	1
Sink	2.25	1

TABLE 12

HOT WATER USE FOR RESIDENTIAL PURPOSES

Function	Hot Water Consumption per Use	
	ASHRAE <u>Design Data</u> (23)	Zanker-Forbach Minitherm <u>Advertising</u>
Wash Hands	2 Gal.	3/4 - 1-1/2 Gal.
Bath	20 Gal.	39-47 Gal.
Shower	15 Gal.	8-12 Gal.

Manufacturers' advertising has only added to the confusion about hot water use and rates of use. Note, however, that in all but one case, the water heater manufacturers have grossly understated flow rates compared to ASHRAE design data. The reason for this may be made clear in the section on energy conservation calculations. The small, instantaneous heaters do not have the capacity to provide a large temperature rise at high flow rates. For example, a 6 kW unit will theoretically raise water temperature about 20F° at 2 gallons per minute and 40F° at 1 gallon per minute. Thus, it appears that advertising may have chosen flow rates compatible with unit capacity. This points out a potential energy conserving strategy of reducing hot water flow. The ASHRAE design data and a few independent faucet flow rate checks suggest that the installation of flow restrictors may be an excellent way to conserve both energy and water. Flow restrictors should have application on residential and commercial lavatories and showers. Shower flow can be reduced to 1-1/2 gallons per minute and lavatory faucet flow, it is claimed, may be reduced to 1/2 gallon per minute when an aerator is combined with the flow restrictor.

The relatively small heating capacity of point-of-use water heaters and the usages shown in Tables 1 through 9 suggest that these small heaters may be of greatest value as booster heaters for residential dishwashers and as primary heaters for lavatories and light duty sinks everywhere. The overall benefits of point-of-use heaters may be enhanced by combining them with lavatory flow restrictors.

WATER HEATING ENERGY USE AND OPERATING COSTS

General Considerations

There are a number of factors to be considered when selecting new water heaters and when analyzing potential retrofit opportunities. This report is concerned only with the possible value and proper selection of point-of-use water heaters. There will, therefore, be no analysis or discussion of other effective energy conservation measures which include the following:

- apply additional insulation to storage water heater tanks, (24,25)
- reduce service water temperature, (26)
- reduce service water flow rate, (27)
- insulate hot water service pipes.

Selection of point-of-use water heaters will be based on a consideration of the following factors:

- energy use and cost of operating a central water heater,
- energy use and cost of operating a point-of-use water heater,
- life cycle cost comparison of available alternatives,
- code and listing agency compliance.

The energy used by any water heater will be affected by the following:

- ground or supply water temperature,
- service water temperature requirement,
- quantity of water used,
- standby heat loss,
- line losses,
- efficiency of water heater

Identification or calculation of each of the above variables will allow one to make a rational comparison of water heater alternatives.

Ground or Supply Water Temperature

This is frequently an uncontrollable variable. Only when point-of-use heaters are used as boosters for storage heaters does a controlled and constant supply temperature enter the calculations.

Service Hot Water Temperature Requirements

General guidelines for hot water temperature are contained in Table 8. These temperatures may be used when comparing water heater alternatives unless, of course, some special temperature requirements pertain. An example of a special requirement might be a photographic processing laboratory. Office buildings and other public facilities which require hot water only for lavatories are a special case as OSHA mandates hot OR tepid water for lavatories.⁽²⁸⁾ Tepid is not defined in the regulation but is assumed to be "warm to the touch" which might be as low as 95°F.

Quantity of Water Used

Quantities of water used by various types of service taps may be estimated from Tables 1, 2, 3, 4, 5, and 6. It is recommended that consideration be given to the installation of flow restrictors on showers and lavatory faucets. Showers may be limited to a flow rate of 1-1/2 gallons per minute and lavatories may be reduced to 1/2 gallon per minute. Aerators are recommended to be used in combination with flow restrictors. Comparisons of water heater alternatives should be based on the final, retrofitted flow rates.

Standby Heat Loss

Storage type water heaters all have standby heat losses. Standby heat loss is the loss of heat from the hot water through the jacket or shell of the heater. A study of these standby losses was included in two studies of the insulation retrofit of water heaters.(29,30) The following two Tables constructed from data in these two reports may be used when calculating the energy use comparisons of water heaters.

TABLE 13
STANDBY HEAT LOSS FROM ELECTRICALLY
HEATED DOMESTIC WATER HEATERS

<u>Temperature Difference</u> ⁽²⁾	<u>BTU per Hour</u> ⁽¹⁾			
	<u>Water Heater Capacity, Gal</u>			
	<u>30</u>	<u>40</u>	<u>50</u>	<u>60</u>
40	250	250	300	300
50	320	320	370	380
60	390	390	440	460
70	460	460	510	540
80	530	530	580	620
90	600	600	650	700

(1) Data presume 1 in. of factory-installed fiber glass shell insulation.

(2) Temperature of water in tank, °F less air temperature in room where heater is located.

TABLE 14
STANDBY HEAT LOSS FROM GAS
HEATED DOMESTIC WATER HEATERS
BTU per Hour⁽¹⁾

<u>Temperature Difference</u> (2)	<u>Water Heater Capacity, Gal</u>	
	<u>40</u>	<u>50</u>
40	700	700
50	800	800
60	1150	1200
70	1350	1420
80	1550	1650
90	1800	2000

- (1) Data presume 1 in. of factory-installed fiber glass shell insulation.
- (2) Temperature of water in tank, °F, less air temperature in room where heater is located.

Thus, a 50 gallon gas storage water heater set for 140°F may cost \$45.65 per year in standby losses where gas costs \$0.367 per therm. Conversely, an electric heater of 50 gallons would cost \$65.06 when electricity costs \$0.0497 per kWh.

It is important to note that standby losses are not "lost" if the water heater is located in conditioned space such as a closet or laundry room. Thus, the location of the existing water heater must be considered when preparing the life cycle costing calculations. The cost of standby losses is a real cost which must be accounted for. However, any standby energy losses saved must be replaced by the heating system if the water heater is in conditioned space.

Line Losses

Line losses are difficult to deal with in energy analyses because they are not a static phenomenon. There are design data which have been successfully used for many years and it is recommended that these data be used for water heater energy analyses. The data to be used in calculation are shown in Tables 15 and 16. (31)

TABLE 15

HEAT LOSS FROM COPPER TUBINGBTU Per Hour Per Foot of Length in Air

<u>Tubing Diameter, in.</u>	<u>Tube to Air Temperature Difference, °F</u>			
	<u>50</u>	<u>60</u>	<u>70</u>	<u>80</u>
3/8	10	12	15	18
1/2	13	15	18	22
5/8	15	18	21	26
3/4	17	21	25	30.

TABLE 16

HEAT LOSS FROM STEEL PIPEBTU Per Hour Per Foot of Length in Air

<u>Pipe Diameter, In.</u>	<u>50° Pipe to Air Temperature Difference</u>
1/2	23
3/4	29
1	35

Heat losses from buried hot water pipes are even more difficult to deal with as one must know the apparent thermal conductivity of the soil involved and at its average moisture content and actual density. Soils may have a "k" factor ranging from 4 to 22. The reader is referred to the ASHRAE Handbook for details dealing with heat loss in buried pipes. (32)

Efficiency of Water Heaters

Analysis and consideration of water heater alternatives should recognize the differences in heat transfer efficiency of various types of heaters. These differences are primarily associated with the energy source although not necessarily attributable to that source. Comparative analytical techniques used in this study may employ general, "handbook" efficiencies when authenticated manufacturers' data are not available for specific units. Efficiencies which may be used are displayed in Table 17.

TABLE 17

TYPICAL EFFICIENCIES OF
DOMESTIC TYPE WATER HEATERS

<u>Type of Heater</u>	<u>Efficiency</u>
Oil-Fired	0.70
Gas-Fired	0.75
Electric	0.95

Calculation of Water Heater Energy Use

The annual energy required to heat water for specific taps within a building may be calculated according to the following equation:

$$H = \frac{8.3 \times V \times N (T_o - T_I)}{E}$$

H = annual energy requirement, BTU
V = gallons per day required from tap
N = number of days per year tap is used
T_o = temperature of hot water required from tap, °F
T_I = temperature of water entering water heater, °F
E = efficiency of water heater

The selection of power rating of instantaneous, point-of-use, electric water heaters may be indicated by the following equation:

$$R = 0.16 \times F \times (T_o - T_I)$$

R = power rating of heaters, kW
F = flow rate from tap, gallons per minute

No general agreement was found concerning the constant multiplier to be used in this equation. A range of values from 0.146 to 0.184 could be justified based on the various inputs obtained during this study.

Inputs for the two equations in this section may be obtained from actual measurements made at taps being considered for retrofit. Alternatively, the tables contained on pages 23 through 37 may be consulted for typical data. The use of typical data, taken from these tables, is acceptable for use in comparative analyses such as making a "yes" or "no" retrofit decision or in selecting between two or more alternate candidates for new water heaters.

Annual water heater energy use by remote and/or storage water heaters must also include standby and/or line losses as was previously discussed. The calculation of estimated total annual energy use is illustrated in the Appendix.

Comparison of standby water heaters to point-of-use water heaters

This study is concerned with point-of-use heaters for individual or just a few taps. Examples include lavatories and domestic dishwashers. The flow rates are usually low being generally less than four gallons per minute per tap and as low as one half gallon per minute per tap. Daily usage is generally low because of infrequent use. These conditions are favorable to the consideration of point-of-use heaters on an energy conservation basis. Life-cycle costing, however, may not always favor selecting a point-of-use heater. The reasons for this include the following factors which are included in the Appendix analyses.

- Installed cost of water heaters is extremely variable.
- energy cost for gas, storage heaters is frequently very low compared to the cost of electricity for point-of-use heaters.
- The annual water usage may be very low for some taps thus generating very low annual savings.

These factors made it impossible to generalize on the potential economic value of point-of-use water heaters. It is recommended that an evaluation of these heaters be made in each of the following circumstances:

- booster heater for domestic dishwasher combined with reduction of storage water temperature;
- replacement of storage water heaters in every building where the only hot (or tepid) water requirement is for lavatory use;
- replacement of storage water heaters in laboratories and other facilities requiring small amounts of controlled temperature hot water.

The Appendix contains methods for making these evaluations as well as sample calculations and life-cycle costs. Facilities Engineers who gain experience with these simple, analytical tools will undoubtedly discover additional applications based upon local conditions, local bid prices and local energy costs.

Storage water heaters will likely continue to find general application in domestic or residential use but may, in many

instances, be operated at a much lower temperature than that currently used. There will likely be a reduced opportunity to incorporate point-of-use water heaters in public buildings, barracks and service buildings with relatively large requirements for hot water from taps other than lavatories.

No consideration has been given to the use of point-of-use water heaters for taps served by central, circulating hot water systems. This was not within the scope of the Task Order and nothing was found in manufacturers' or technical literature pertaining to such a study. It may be worthwhile to consider this in the near future. This sort of study would possibly require on-site, engineering evaluation of various types of taps in facility circulation systems before any conclusions might be reached. This study could be made in phases with the first phase limited to greatest potential opportunities by measuring line losses to remote, low volume points of use.

Also, note that large point-of-use heaters serving large demand buildings were not included in this study. These heaters may include steam heat exchangers and direct fired units. The applicability of such units to some facilities requirements such as food service and hospitals might be another subject worthy of study.

A final factor which is illustrated in the Appendix is the use of point-of-use water heaters in new construction. The only difference in analysis in this case might be elimination of hot water lines to serve lavatories and other taps having a flow rate/temperature rise demand which could be met by point-of-use heaters.

How To Select a Point-of-Use Water Heater

The Appendix contains methods of analysis and sample calculations for determining whether or not to install a point-of-use heater. These same methods may also be applied to selecting among the various heater candidates. It is possible to generalize on the selection of a specific heater. The deciding factor in most instances will be installed price. The least costly heater of the proper capacity will generally be the best choice. There are two types of heaters to consider - instantaneous and small or mini-storage heaters. Deciding between the two types will be influenced by the following considerations.

- What temperature rise and flow rate are required?

Some instantaneous heaters have very limited capacity as is illustrated on page 16. Capacity of small, point-of-use storage units is difficult to determine. Recently proposed DoE guidelines for measuring recovery rate and first hour usage⁽³³⁾ may produce a useful labeling of storage heaters. Until this happens, purchasers must rely on manufacturers' recommendations for the proper size heater for each proposed application. It does seem that a 1 gallon, 1 kW heater should be adequate for providing tepid water for 2 flow restricted lavatory taps in an office building. This size tank would require a larger heater, possibly 2 kW, to serve as a booster for domestic dishwashers.

- How much space is available for installation?

Some small storage tanks may not fit in the allotted space.

- Is there a need to vary or adjust temperature?

Instantaneous units usually do not have an adjustable thermostat and many require an additional, adjustable tempering valve to meet varying temperature requirements. Most small storage units have an adjustable thermostat.

- Does supply water temperature vary?

Instantaneous units provide a fixed temperature rise. Thus, if a unit is selected to provide tepid (95°F) water using a summer groundwater temperature of 65°F, the tap water temperature will drop to 70°F when winter groundwater temperature drops to 40°F. It may be necessary to purchase an oversized instantaneous unit combined with an adjustable tempering valve in areas where groundwater of widely fluctuating temperature supplies an instantaneous unit. An alternate consideration is to use instant units only as boosters for storage units with reduced service temperature.

- What is the installed cost of each of the various units?

It is impossible to offer comparative estimates of installed costs because of many variables involved including possible need for upgraded electrical service, and other possible accessories and a great disparity in quoted prices for any given model of water heater. Representative selling prices which were quoted on some water heaters appear below.

Instant Heaters

Minitherm	6kw	\$169 retail
Instant Flow (sizes available at this price not disclosed)		\$120 retail \$235 installed
Hot Line	10kw	\$279.95 retail
	15kw	\$299.95 retail
	20kw	\$329.95 retail

Small or Mini Storage Heaters

In-Sink-Erator	\$ 91 retail
Electric Heater CE110	\$152 retail

Replacement 50 Gal Storage Heater

Electric	\$150 retail for heater
	89 labor
	<u>\$239</u> total

Gas	\$170 material
	103 labor
	<u>\$273</u> total

Retail prices ranged from 1-3/4 to 2-1/3 times the lowest wholesale prices. Volume discounts were found, suggesting that large retail suppliers might sell for a lower price than small retail suppliers. There was even an indication that some manufacturers would offer quotations for sale directly to Army facilities. The best suggestion that can be offered concerning price is to obtain competitive bids from plumbing contractors for installed price; from plumbing equipment suppliers for material only; and solicit quotations for direct sale from each manufacturer.

- How do you select the proper size unit?

This question may best be answered by your local plumbing contractor or supplier who has been trained to select the proper size water heater. Table 18 contains guidelines for selecting the proper kW rating of instantaneous heaters.

TABLE 18

KILOWATT RATINGS FOR INSTANT WATER HEATERS

BASED ON REQUIRED TEMPERATURE RISE AND FLOW RATE

Tap Flow Rate, gpm	$T_o - T_i$				
	20	40	60	80	100
1/2	1.6	3.2	4.8	6.4	8.0
1	3.2	6.4	9.6	12.8	16.0
1-1/2	4.8	9.6	14.4	19.2	-
2	6.4	12.8	19.4	-	-
2-1/2	8.0	16.0	-	-	-
3	9.6	19.2	-	-	-

The area to the left of and above the stepped line indicates the only circumstances where 110 volt service may be used for currently available heaters. The blank spaces indicate that there is no single, instant, point-of-use heater which will provide the indicated temperature rise at each flow rate. It is apparent that instant water heaters may be useful only as boosters for domestic dishwashers where they can raise the temperature of 100°F-120°F warm water up to the desired 140°F and at typical flow rates of 3 gpm. The other potential uses should be considered in combination with flow restrictors such as 1-1/2 gallons per minute maximum for showers and 1/2 gallon per minute maximum for lavatories.

- Will water supply to heater be uninterrupted?

Some instantaneous, point-of-use heaters may burn out if air should flow through the heater. This is not a potential hazard with small tank heaters.

Life Cycle Costing

The Appendix contains examples of Life Cycle Costing according to DoE procedures⁽³⁴⁾ for 19 different situations. The life of a conventional storage heater was taken at 10 years. Thus a study period of 10 years in each instance was used. These examples may be followed for each local decision-making circumstance. Conclusions should not be drawn from the examples because of the wide range of installed prices which will be encountered in the market place.

CONCLUSIONS

Point-of-Use water heaters offer the potential for major reductions in the energy used to heat water in many types of Army facilities such as housing, offices, training buildings and outposts.

The major reduction in energy use achievable with point-of-use water heaters may be accompanied by an increase in annual operating cost in cases where an existing storage water heater is fueled by gas or oil.

The selling prices of point-of-use water heaters are highly variable being influenced by trade discounts, wholesale discounts, volume discounts and direct sale quotations. Lowest to highest selling price differential for a given make and model may exceed 100 percent.

Each individual opportunity to use a point-of-use water heater must be separately analyzed for life-cycle cost based on price and installation quotations and applicable energy prices because of the strong impact of appliance and energy price variations on the analysis.

RECOMMENDATIONS

Point-of-use water heaters should be considered for use wherever any one of the following conditions exist:

- building daily demand for hot water is low,
- the principle use of hot water in the building is in lavatories,
- the only requirement for "hotter-than-120°F" water is for a domestic dishwasher.

Follow the examples in the Appendix of this report to select the proper type and size of heater and to make energy use and life-cycle cost analyses.

Make all calculations based on current price quotations for the various appliances.

Supply only tepid (warm-to-touch) water to lavatory basins.

Solicit price quotations directly from the appliance manufacturers.

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- ¹⁶Ibid; 1976 Systems, 37.9.
- ¹⁷Ibid; 1976 Systems, 37.11.
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- ²⁷ Ibid.
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- ³⁰ Slaughter, op.cit.
- ³¹ ERDA, op.cit.
- ³² ASHRAE Handbook, 1977 Fundamentals, 22.9.
- ³³ Federal Register; Vol. 44; No. 91, 2719; May 9, 1979.
- ³⁴ Ibid.
- ³⁵ Cook, op.cit.
- ³⁶ Moselle, G., Ed; National Construction Estimator; Craftsman; 1977.
- ³⁷ Federal Register; Part IV; April 30, 1979.

APPENDIX

Selection of point-of-use water heaters will be dependent on energy savings and cost effectiveness based on life cycle cost analysis. Each retrofit and new construction opportunity must be analyzed to determine, on a comparative basis, if a point-of-use heater will offer benefits. Separate analysis of each opportunity is a necessity because of the variations in water heater prices and regional energy costs. Three sample calculations are shown in this Appendix and should provide the reader with sufficient guidance for making his own calculations. A study period of 10 years has been used in all cases because of the estimated service life of current storage heaters. Many point-of-use heaters, especially the instantaneous type, have not had sufficient experience in the market place to permit assigning a longer study period. The three examples to be used for illustrating energy analysis and life cycle costing include:

- domestic dishwasher retrofit,
- office building laboratories and slop sink retrofit,
- flight training facility lavatories and slop sink new construction.

Domestic Dishwasher Retrofit Example

Energy conservation analysis should precede life cycle cost analysis. In this example, we are assuming a six room, 1500 square foot residence, located in DoE Region II. The family of five does one dishwasher load per day, 340 days per year. The house has a 50 gallon, natural gas fired, hot water heater set at 140°F and located 20 feet from the dishwasher.

The hot water heater could be set down to 120°F if it were not for the 140°F water required for proper dishwasher operation. Natural gas cost is presently \$3.95 per 1,000,000 BTU and electricity costs \$0.061 per kWh. In the analysis we will compare an instantaneous and a small tank point-of-use heater to the existing operating conditions in which the dishwasher requires 15 gallons of hot water in 45 minutes with 5 fills of 3 gallons each. Groundwater temperature averages 50°F during the year (range 39°F-61°F).

The first step is to determine the size of the point-of-use heater required. The size, or kW rating, of the

instantaneous heater is determined from the equation on page 48.

$$R = 0.16 F (T_o - T_i)$$

R = kW rating

F = 3 gallons per minute

T_o = 140°F required for dishwasher

T_i = 120°F input to point-of-use booster heaters from hot water system

$$R = 0.16 \times 3 \times (140 - 120)$$

$$R = 9.6 \text{ kW}$$

(Note that a 3 kW unit from Chronomite could be considered IF a one gallon per minute flow restrictor were installed. It should be determined from the dishwasher manufacturer if such a low flow rate will influence machine operation or manufacturers' guarantee.)

The correct size for a mini-tank point-of-use heater cannot be calculated from available information and manufacturers' representatives must be consulted. In this case of a dishwasher requiring 15 gallons at intermittent flows of 3 gallons at a rate of 3 gallons per minute and a 20°F temperature rise, the recommendation may be for a one gallon tank with a 1 kW heater, switch controlled so that it is manually turned on about 10-15 minutes prior to each dishwashing and turned off at the completion of each dishwashing. The heater thermostat would be set for 180°F and a 2:1 tempering valve would be installed to dilute the 180°F water with 120°F service hot water.

Hot water energy use calculations for the entire household must be made as the before and after circumstances involve different thermostat settings for the 50 gallon tank-type water heater.

Present Energy Use

Hot water use for a typical residence is 560 gallons per

week. (35) Annual use would then be 29,120 gallons. Annual energy use associated with this use would be comprised of:

- energy to heat 29,120 gallons from 50°F, to 140°F
- standby losses,
- line losses from (assumed) 40 feet of 1/2 inch copper pipe

These elements are calculated as follows:

- Heating energy

$$E = \frac{8.3 \times G \times (T_o - T_i)}{e}$$

E = BTU per year

G = gallons per year

T_o = tank temperature, °F

T_i = inlet water temperature, °F

e = heater efficiency

So, in this example:

$$E = \frac{8.3 \times 29,120 \times (140 - 50)}{0.75}$$

$$E = 29,003,520 \text{ BTU/year}$$

- Standby loss

The loss from a 50 gallon gas heater set for 140°F in a room at 70°F is taken from Table 14 as 1420 BTU per hour or 12,439,200 BTU per year.

- Line losses

The line losses from 40 feet of 1/2 inch copper pipe are not great and are difficult to estimate because it is not a static circumstance. For example, there are times during a day when the water in the pipes may cool to ambient temperature because the house may be unoccupied for 8-10 hours. Forty feet of 1/2 inch pipe contains only about 1-1/2 gallons. If this cooled from 140°F to 70°F twice a day, the annual heat loss would be 330,885 BTU for an annual cost of \$1.31 in this example. And, this amount should be reduced by the space

heating value of the hot water pipes. Every BTU transferred to areas within the conditioned building envelope is a BTU that will not be required from the space heating system.

Static loss calculation approaches produce similarly small figures. Per year, 6,307,200 BTU would be lost from 40 feet of copper pipe at 140°F in 70°F space. Since the pipe is at 140°F only when hot water is in use, the actual line loss by this method would more than likely be closer to 1/10th of 6,307,200 BTU.

Therefore, line losses in residential circumstances have been ignored for the purpose of making comparative calculations.

The total annual energy use for the existing water heater in this example is then heating energy plus standby loss.

$$29,003,520 + 12,439,200 = 41,442,720 \text{ BTU per year}$$

The annual cost in this case would be:

$$\frac{\$3.95 \times 41,442,720}{1,000,000} = \$163.70$$

First Alternate-Instantaneous Heater

The existing heater's thermostat has been turned down to 120°F and the water for the dishwasher is piped through a 10 kW heater. The 15 gallon dishwasher is used 340 times per year. The annual hot water energy usage will now be composed of energy to heat water to 120°F in the storage heater; stand by loss at 120°F; and the energy required to heat 15 X 340 = 5,100 gallons from 120°F to 140°F in the instantaneous heater.

- Heating energy

$$E = \frac{8.3 \times G \times (T_o - T_i)}{e} = \frac{8.3 \times 29,120 (120 - 50)}{0.75}$$

$$E = 22,558,293 \text{ BTU/year}$$

- Standby loss

Take from Table 14 = 800 BTU per hour or 7,008,000 BTU/Yr.

- Point-of-use heater operation

The dishwasher uses 15 gallons per use with 5-1 minute fills of 3 gallons each 340 times at 120°F and a 20°F rise. Annual energy use may be calculated two ways.

$$\begin{aligned}
 E &= \frac{8.3 \times G \times (T_o - T_i)}{e} \\
 &= \frac{8.3 \times (15 \times 340) \times (140 - 120)}{0.95} \\
 &= 891,158 \text{ BTU per year}
 \end{aligned}$$

or,

hours of 10 kW heater operation

$$E = 10 \text{ kW} \times \frac{5 \text{ Min per day}}{60} \times 340 \times \frac{3413 \text{ BTU}}{\text{kW}}$$

$$E = 967,017 \text{ BTU per year}$$

This latter figure will be closer to the actual energy consumed. Annual energy used in this situation is therefore:

$$\begin{array}{r}
 22,558,293 \\
 7,008,000 \\
 \hline
 967,017 \\
 \hline
 30,533,510 \text{ BTU per year}
 \end{array}$$

The annual cost would be:

$$\begin{array}{r}
 \$3.95 \times 29,566,293 = \$116.79 \\
 \hline
 1,000,000 \\
 + \$0.061 \times 967,017 = \$17.28 \\
 \hline
 3413 \qquad \qquad \$134.07
 \end{array}$$

And, the savings for this first year would be:

$$\begin{aligned}
 \$163.70 - 134.07 &= \$29.63 \text{ per year.} \\
 41,442,720 - 30,533,310 &= 10,909,410 \text{ BTU per year}
 \end{aligned}$$

It is interesting to note that if the 50 gallon storage heater in this example had been electrically heated, the annual savings would have appeared as \$194.98.

Second Alternate - Mini-Tank Heater

Some of the data developed under the first alternate will apply.

- Heating energy = 22,558,293 BTU/year
- Standby loss = 7,008,000 BTU/year
- Point-of-use heater operation

Use the hours of 1 kW heater operation example. Turn the heater on 15 minutes before dishwashing for a 45 minute cycle. The heater will operate almost continually for 1 hour.

$$E = 1 \text{ kW} \times 1 \text{ hr} \times 340 \times 3413 = 1,160,420 \text{ BTU per year}$$

Total annual usage is then,

$$\begin{array}{r} 22,558,293 \\ 7,008,000 \\ 1,160,420 \\ \hline 30,726,713 \text{ BTU per year} \end{array}$$

$$\begin{array}{r} \text{The annual cost would be: } + \$0.061 \times 1,160,000 = 116.79 \\ 20.74 \\ \hline 137.53 \end{array}$$

And, the savings for the first year would be:

$$\begin{array}{r} \$163.70 - 137.53 = 26.17 \text{ per year} \\ 41,442,720 - 30,726,713 = 20,716,007 \text{ BTU per year} \end{array}$$

It appears from this example, that a 10 kW instant point-of-use heater might have a slight advantage over a 1 kW, 1 gallon mini-tank heater. Life cycle costing of the alternatives as illustrated on page 62 may, however, dictate a different conclusion based solely on economics of the various circumstances. Installed cost of the various heater alternatives can have a strong bearing on the decision making process. Consider the following estimates of installed cost using labor charges from the National Construction Estimator. (36)

TABLE A-1
INSTALLED COST ESTIMATES

Instantaneous Heater - 10 kW		Mini-Tank Heater 1 gal-1 kW	
Retail List Price	\$279.95	Retail List Price	\$152.00
Run 240V/ 45 amp line	50.00	Extend 110V line w/ switch	18.00
Plumbing Connection	67.00	Plumbing Connection	74.00
Permits	<u>15.00</u>	Permits	<u>15.00</u>
Total plus any applica- ble taxes	\$411.95		\$259.00

Life Cycle Cost

The methods to be used for Life Cycle Costing are found in the Federal Register⁽³⁷⁾. All of the needed data have been developed. Note that we are ignoring the very small line losses. The potential savings due to reduced corrosion and calcification attributable to a 20°F drop in storage water temperature are assumed to extend existing water heater life by one year and there are, for this example, 5 years of life left in the old heater. The data required for Life Cycle Cost analysis are as follows:

TABLE A-2
LIFE CYCLE COST INPUTS

	Do Nothing	Install Instantaneous Heater	Install Mini-Tank Heater
Annual Energy Cost, in 1980	\$163.70	\$134.07	\$137.53
Install Booster Heater in 1980	\$ 0.00	\$411.95	\$259.00
Replace Water Heater in 1985, 1980 dollars	\$272.70	\$ 0.00	\$ 0.00
Replace Water Heater in 1986, 1980 dollars	\$ 0.00	\$272.70	\$272.70

TABLE A-3
LIFE CYCLE COST ANALYSIS
ASSUME DOE REGION 11

	<u>Do Nothing</u>	<u>Install Instant Heater</u>	<u>Install Mini Tank Heater</u>
A. Purchase - Cost and Labor	-	\$ 411.95	\$ 259.00
B. Annual Energy Cost			
Gas	\$ 163.70	116.79	116.79
Electric	-	17.28	20.74
C. Present Worth Factor 10 yrs.			
Gas	7.117	7.117	7.117
Electric	6.113	6.113	6.113
D. Life Cycle Energy Cost B x C			
Gas	1165.05	831.19	831.19
Electric	-	105.63	126.78
E. Replace Water Heater			
1985 - 272.70 X .6209	169.32	-	-
1986 - 272.70 X .5645	-	153.94	153.94
F. Total Life Cycle Cost A + D + E	\$1334.37	\$1348.77	\$1370.91

COMMENTARY:

The 10 year life cycle costs are very similar. Regional variations in bid price for instant heaters and differences in DOE PW factors for the various regions might influence the comparisons significantly. The major energy use reduction afforded by point of use heaters makes them a worthwhile consideration for domestic dishwasher service only when their use permits a 20 F or so set back of the storage heater.

Office Building Laboratories Retrofit Example

We are assuming, in this example, a 35 year old, 2 story barracks building which has been converted to low-density office space. The old shower stalls are not required. There is one lavatory on each of the two floors plus one slop sink. Each lavatory contains 6 basins but 4 have been disconnected. Building occupancy is 25 persons, 8 hours per day, 5 days per normal week, 250 total days per year. Hot water to the two lavatories and slop sink is supplied by an oil fired, 30 gallon heater with thermostat set at 120°F. Groundwater temperature averages 45°F (range 35°F-55°F). Fuel oil costs \$0.85 per gallon which is equal to \$6.07 per 1,000,000 BTU. Electricity is billed at \$0.050 per kWh or \$14.60 per 1,000,000 BTU. We will, as in the prior case, compare instantaneous and small tank point-of-use heaters to the existing circumstances.

The first step is to determine the size of point-of-use heaters required for each lavatory and slop sink. The temperature required is 95°F (tepid) at each lavatory and 120°F at the slop sink. Water usage is determined from Tables 9 and 10.

Lavatory,	2-1/2 gal/min	3 x 25 gal/day
1 basin	flow rate per basin	total for 4 basins
slop sink	3-3/4 gal/min	10 gal/day
	flow rate	

Each lavatory will require one heater whose maximum flow rate will be $2\frac{1}{2} + 2\frac{1}{2} = 5$ gallons per minute. The temperature must be based on the lowest annual groundwater temperature to meet the mandated tepid water requirement. AND, the temperature at the highest annual groundwater temperature should not exceed 120°F to guard against scalding.

$$R = 0.16F (T_o - T_i)$$

F = 5 since one heater must occasionally supply 2 faucets

$$R = 0.16 \times 5 \times (95 - 35)$$

$$R = 48 \text{ kW}$$

No commercial 50 kW heater was found in this study. The largest unit found was 20 kW. It is obvious that a straightforward retrofit with off-the-shelf instantaneous heaters is not possible. An alternative involving flow restrictors will be considered later on because the required 60°F minimum rise at 5 gallons per minute cannot be achieved with instant heaters.

The correct size for a mini-tank heater cannot be calculated from available information and manufacturers' representatives must be consulted. A maximum 5 gallons per minute flow rate and 38 gallons per day can easily be met by a small unit. The 1/2 gallon Ultra-Warm could meet the requirement but 2 units would be needed because a special faucet is required. A 1 kW, 1 gallon unit such as the Hubbell from the previous example is, therefore, used again. This type of unit is the only one capable of meeting the requirements. Three units are required, one for each lavatory and one for the slop sink. Energy use calculations proceed as follows.

Present Circumstances

- Heating energy for lavatories

$$E = \frac{8.3 \times G \times (T_o - T_i)}{e}$$

$$G, \text{ gal per year} = 3 \times 25 \times 250$$

$$= \frac{8.3 \times 3 \times 25 \times 250 \times (120 - 140)}{0.70}$$

E = 16,674,107 BTU per year

- Heating energy for slop sink

$$\frac{8.3 \times 10 \times 250 \times (120 - 45)}{0.70}$$

E = 2,223,214 BTU per year

- Standby loss

The loss from a 30 gallon oil heater set for 120°F in a 60°F (average) room cannot be determined from the literature. It can be very roughly estimated from Tables 13 and 14 at 1000 BTU per hour or 8,760,000 BTU per year.

- Line losses

One hundred twenty feet of 1/2 inch water pipe are in the building and contain about 5 gallons. Daily use is 85 gallons, so it is assumed that line losses are, again, very small compared to total energy demand of the heater. The total annual energy use for the existing water heater in this example is then heating energy plus standby loss:

$$16,674,107 + 2,223,204 + 8,760,000 \\ = 27,657,321 \text{ BTU per year}$$

The annual cost in this case would be:

$$\frac{\$6.07 \times 27,657,321}{1,000,000} = \$167.88$$

First Alternate Instantaneous Heaters

It was shown that there is no heater available to provide a 60°F temperature rise at a flow rate of 5 gallons per minute.

Second Alternate- Mini-Tank Heaters

Three heaters will be required. One is needed for each lavatory (2 basins each) and one is needed for the slop sink.

The units will be "always on" and set for 140°F with a tempering valve to supply tepid water for the basins and 120°F water for the slop sink.

- Heating energy for each lavatory (2 basins)

$$E = \frac{8.3 \times G \times (T_o - T_i)}{e}$$

$$= \frac{8.3 \times (37-1/2 \times 250 \text{ gal/yr}) (95 - 45)}{0.95}$$

$$= 9,828,946 \text{ BTU per year}$$

- Heating energy for slop sink

$$= \frac{8.3 \times (10 \times 250) (120 - 45)}{0.95}$$

$$= 1,638,158 \text{ BTU per year}$$

- Standby losses

No data have been published for standby losses from small, 1 gallon heaters. An estimate can be made from Table 13 using the ratio of tank surface areas which are:

30 gallon tank 3391 square inches

1 gallon tank 297 square inches

lavatories and slop sink - 3 units set at 140°F

$$(3) (460) \text{ BTU per hour} \times 24 \times 365 \times 297/3391 = 1,058,795 \text{ BTU per year}$$

The total annual energy use for this alternative is then heating energy plus standby loss:

$$9,828,946 + 1,638,158 + 1,058,795 = 12,525,899 \text{ BTU per year}$$

The annual cost in this case would be:

$$\frac{\$14.60 \times 12,525,899}{1,000,000} = \$182.88$$

and the savings for the first year would be:

$$\$167.88 - 182.88 = \$15.00 \text{ per year INCREASE}$$

$$27,657,321 - 12,525,899 = 15,131,422 \text{ BTU per year DECREASE}$$

This alternative does not present the greatest potential for energy savings. Restriction of water flow would reduce hot water usage; would permit consideration of two different types of point-of-use heaters; would reduce the cost of installing the mini-tank heater by eliminating the tempering valve; would nearly eliminate mini-tank standby losses. We have assumed a 2-1/2 gallon per minute flow rate and 3 gallons per person per day. Flow rate may be restricted to 1/2 gallon per minute with an aerator at lavatory basins. This has been estimated to reduce per-person-per-day usage to 2 gallons. Slop sink flow rate can be reduced to 1-1/2 gallons per minute but this would not affect the 10 gallons per day used for janitorial purposes. The age of the plumbing fixtures in the building is such that faucets must be replaced to allow the attachment of flow restricting aerators.

Third Alternate-Instantaneous Heaters with New Faucets

Remember, that three heaters will be required and that we must design for simultaneous operation of 2 faucets at the lowest annual groundwater temperature.

- Heating energy for each lavatory

$$R = 0.16 (1/2 + 1/2) (95 - 35)$$

$$= 9.6 \text{ kW}$$

- Check maximum temperature (one faucet case) at highest groundwater temperature

$$R = 0.16 F (T_o - T_i)$$

$$9.6 = 0.16 (1/2) (T_o - 55)$$

$$T_o = 175^\circ\text{F}$$

It is obvious that this is a highly dangerous temperature for a wash basin and, therefore, one instant heater cannot

serve 2 basins at the extremes of usage (1 basin - 2 basins) and the extremes of groundwater temperature (35°F - 55°F). One 4.8 kW heater must therefore be used on each of the 4 basins in the office building. This installation will then provide a service water temperature range of 95°F (tepid) to 115°F (non-scalding). Chromomite sells a unit rated at 4.6 kW which should be adequate.

With slop sink flow now reduced to 1-1/2 gallons per minute, the proper size instant heater is

$$R = 0.16 (1.5) (120 - 35)$$

$$= 20.4 \text{ kW}$$

- check maximum temperature at highest groundwater temperature (one faucet case)

$$20.4 = 0.16 (1.5) (T_o - 55)$$

$T_{out} = 140^\circ\text{F}$, which is not too hot for janitorial use.

Key Energy System Offers a 20 kW unit.

- Heating energy for each lavatory (4 basins)

$$E = \frac{8.3 \times (12-1/2 \times 250) \left(\frac{95 + 115}{2} - 45 \right)}{0.95} = 1,638,158$$

4 basins = 6,552,632 BTU per year

- Heating energy for slop sink

$$\frac{8.3 (10 \times 250) \left(\frac{120 + 140}{2} - 45 \right)}{0.95} = 1,763,750$$

The total annual energy use for this alternative is then:

$$6,552,532 + 1,763,750 = 8,316,382$$

The annual cost in this case would be:

$$\frac{\$14.60 \times 8,316,382}{1,000,000} = \$121.42$$

Fourth Alternate - Mini-Tank with Self-Contained Mixing Faucet

Only two units of this type were found, the In-Sink-Erator Ultra-Warm and Ultra-Hot. The Ultra-Warm would be suitable for the lavatory basins. Manufacturers' data were not complete, but it appeared that the unit is capable of supplying tepid water from 35°F groundwater at these low lavatory use rates using a 0.75 kW heater model. The unit, with its small capacity, would not service the slop sink.

- Heating energy for each lavatory

$$E = \frac{8.3 \times (12-1/2 \times 250)}{0.95} (95 - 45) = 1,365,132 \text{ BTU per year}$$

4 basins = 5,460,528 BTU per year

This energy use is less than used by instant units because a thermostat permits maintaining a constant, year round service temperature.

- Standby loss

Once again, we must estimate standby losses in the absence of manufacturers' data or literature references. The unit normally maintains 1/2 gallon of 190°F water and the estimated standby loss for 4 units is:

$$\Delta T = 190 - 70 = 120^\circ\text{F}$$

From Table 13 take twice the loss for 60°F temperature difference = $2 \times 390 = 780 \text{ BTU/hr}$

$$4(780 \text{ BTU/hr}) \times 24 \times 365 \times 297/3391 = 1,196,899 \text{ BTU/yr.}$$

The total annual energy use for the basin in alternative four is:

$$5,460,528 + 1,196,899 = 6,657,427 \text{ BTU per year PLUS}$$

slop sink alternative from second alternate - 1,638,158
plus its standby loss of 352,932 BTU per year.

or

$$1,991,090 \text{ BTU per year.}$$

The total annual energy use for this alternate is then:

$$6,995,003 + 1,638,158 + 352,932 = 8,986,093$$

Fifth Alternate Mini-Tank with New Faucets and Flow Restrictors

The incorporation of 1/2 gpm flow restrictors will permit setting the two lavatory tank thermostats down to the desired service temperature and eliminate the tempering valves.

- Heating energy for each lavatory (2 basins)

$$E = \frac{8.3 \times (25 \times 250) (95 - 45)}{0.95} = 2,630,263 \text{ BTU per year}$$

2 lavatories, 4 basins = 5,460,526 BTU per year

- Heating energy for slop sink

1,638,158 from second alternate.

There is no benefit to installation of a flow restrictor unless it will reduce the size of the heater, thermostat setting or annual use.

- Standby loss

Reducing storage temperature to 95°F in the two lavatories will reduce standby loss to a negligible amount. Therefore, the standby loss for the slop sink only is considered from the second alternate.

$$\frac{1,058,795}{3} = 352,932 \text{ BTU per year}$$

The total annual energy use for this alternate is the heating energy plus standby loss:

$$5,450,526 + 1,638,158 + 352,932 = 7,451,616 \text{ BTU per year}$$

The annual cost would be:

$$\frac{\$14.60 \times 7,451,616}{1,000,000} = \$108.79$$

There are, of course, more alternatives to consider than those detailed above. All of the possible alternatives, their annual energy use, and cost are summarized in Table A-4. Table A-5 summarizes all of the inputs for life cycle cost analysis which is displayed on page 74.

TABLE A-4 - SUMMARY OF WATER HEATER ALTERNATIVES

Lavatory Basin Heater (s)	Slop Sink Heater	Flow Re- strict- ors	Water Use		Stand-by Loss, BTU/Yr. Basins	Slop Sink	Total Annual Energy Demand Btu/Yr.	Total Annual Energy Cost
			Basins	Energy Demand, BTU/Yr. Slop Sink				
Storage	Storage	No	16,674,107	2,223,214	8,760,000	-	27,657,321	\$167.88
Instant	Instant	No	WILL	NOT	APPLY			
1 Gal. Tank	1 Gal. Tank	No	8,190,790	1,638,158	705,863	352,932	10,887,743	158.96
Instant	Instant	Yes	6,552,632	1,763,750	-	-	8,316,382	121.42
Instant	1 Gal. Tank	Yes	6,552,632	1,638,158	-	352,932	8,543,722	124.74
1/2 Gal. Tank	Instant	Yes	5,460,528	1,763,750	1,196,899	-	8,421,177	122.95
1/2 Gal. Tank	1 Gal. Tank	Yes	5,460,528	1,638,158	1,196,899	352,932	8,648,517	126.27
1 Gal. Tank	Instant	Yes	5,460,526	1,763,750	-	-	7,224,276	105.47
1 Gal. Tank	1 Gal. Tank	Yes	5,460,526	1,638,158	-	352,932	7,451,616	108.79

TABLE A-3

SUMMARY OF LIFE CYCLE COSTING INPUTS

Retrofit Configuration	No	1 Gal Tank	Instant	Instant	1/2 Gal Tank	1/2 Gal Tank	1 Gal Tank	1 Gal Tank
Basin Heaters	No	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank
Slop Sink Heater	No	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank
Purchase Replacement Heater in 6th Year - 1980 Installed Cost	\$210.00	-	-	-	-	-	-	-
Purchase 3 - 1 Gal Heaters	-	\$456.00	-	-	-	-	-	\$456.00
Purchase 2 - 1 Gal. Heaters	-	-	-	-	-	-	\$304.00	-
Purchase 1 - 1 Gal Heater	-	-	-	\$152.00	-	\$152.00	-	-
Purchase 4 - 4.6 kw Instant	-	-	\$480.00	480.00	-	-	-	-
Purchase 1 - 20 kw Instant	-	-	300.00	-	\$300.00	-	300.00	-
Purchase 4 - 1/2 Gal Heaters	-	-	-	-	364.00	364.00	-	-
Extend 110V Line (1)	-	-	-	18.00	-	-	-	-
(2)	-	-	-	-	-	-	36.00	-
(3)	-	44.00	-	-	-	-	-	44.00
(4)	-	-	-	-	72.00	-	-	-
(5)	-	-	-	-	-	90.00	-	-
Install 220V Line(4)	-	-	200.00	200.00	-	-	-	-
Install 240V Line(1)	-	-	50.00	-	50.00	-	50.00	-
Plumbing Connections	-	222.00	335.00	342.00	335.00	342.00	201.00	201.00
Total Installed Cost	-	722.00	1365.00	1192.00	1121.00	948.00	891.00	701.00
Annual Energy Cost In 1980	\$167.88	\$158.96	\$121.42	\$124.74	\$122.95	\$126.27	\$105.47	\$108.79

TABLE A-6
LIFE CYCLE COST ANALYSIS
ASSUME DOE REGION III

Retrofit Configuration	Present	1 Gal Tank	Instant	Instant	1/2 Gal Tank	1/2 Gal Tank	1 Gal Tank	1 Gal Tank
Basin Heaters	Present	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank
Slop Sink Heaters	Present	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank	Instant	1 Gal Tank
A. Purchase - Cost and Labor		\$ 722.00	\$1365.00	\$1192.00	\$1121.00	\$ 948.00	\$ 891.00	\$ 701.00
B. Annual Energy Cost								
Oil	\$ 167.88							
Electric		158.96	121.42	124.74	122.95	126.27	105.47	108.79
C. Present Worth Factor, 10 yrs.								
Oil	7.528							
Electric		6.455	6.455	6.455	6.455	6.455	6.455	6.455
D. Life Cycle Energy Cost B X C								
Oil	1263.80							
Electric		1026.09	783.77	805.20	793.64	815.07	680.81	702.24
E. Replace Water Heater 1986 - \$210 X .5645	118.54							
F. Total Life Cycle Cost A + D + E	1550.22	1748.09	2148.77	1997.20	1914.64	1763.07	1571.81	1403.24

COMMENTARY:

Here is one case where the lowest cost alternative will produce a 73% reduction in energy use. Note that savings were achieved by combining flow restrictors with point-of-use heater. Point-of-use heaters installed without flow restrictor produced a major increase in life cycle cost.

It is important to note that in only one of the seven examples were point-of-use heaters applicable without hot water system modifications. The major portion of the savings in the remaining examples were directly attributable to the installation of flow restrictors, sometimes accompanied by a reduced storage temperature in the point-of-use heaters.

New Flight Simulator Building Example

The data required for this example are essentially the same as used in the office building example. The building being designed calls for two lavatories with 2 basins each requiring tepid water and 1 slop sink requiring 120°F water. Flow restrictor faucets are called for in the design of the building with 1/2 gallon per minute at the basins and 2 gallons per minute at the slop sink. Occupancy/water use is the same as in the office building example. Groundwater average temperature is 60°F with a range of 55°F-65°F. The alternatives to be considered in design are one storage heater, 30 gallons, gas heated versus the seven alternatives calculated in the office building example. Natural gas costs \$3.67 per 1,000,000 BTU and electricity costs \$14.56.(38) The design of new facilities in this example introduces a new cost consideration. The point-of-use water heaters will make it possible to eliminate 120 feet of 3/4 inch copper pipe from the building construction. Annual energy use and cost calculations are summarized below using the format of calculations from the previous example.

Storage Heater

- Heating energy for lavatories

$$\frac{8.3 \times 2 \times 25 \times 250 (120 - 60)}{0.75} = 8,300,000 \text{ BTU per year}$$

(NOTE: If thermostat setting reduced to 95°F, the annual use would be 4,841,667 BTU)

- Heating energy for slop sink

$$\frac{8.3 \times 10 \times 250 (120 - 60)}{0.75} = 1,660,000 \text{ BTU per year}$$

- Standby loss

The heater is now in conditioned space (70°F)

$$800 \text{ BTU per hour} \times 24 \times 365 = 7,008,000 \text{ BTU per year}$$

Some analysts may choose to ignore this figure since the heat is not "lost" when the water heater is in conditioned space (slop sink closet). However, the tank to air heat transfer does generate an operating cost which must be accounted for in the life cycle cost analysis.

- Total annual energy use

$$8,300,000 + 1,660,000 + 7,008,000 = 16,968,000 \text{ BTU per year}$$

$$\frac{\$367 \times 16,968,000}{1,000,000} = \$62.27 \text{ per year}$$

First Alternate - Instant Heater

- Recheck basin heater size for 65°F and 55°F.

$$R = 0.16 (1/2) (95 - 55)$$

$$R = 3.2 \text{ kW}$$

$$3.2 = 0.16 (1/2) (T_o - 65)$$

$$T_o = 105$$

A 3 kW, 110 V unit may now be used.

- Heating energy for each lavatory (4 basins)

$$\frac{8.3 \times 12\frac{1}{2} \times 250 \left(\frac{95 + 105}{2} - 60 \right) \times 4}{0.95} = 4,368,421 \text{ BTU per year}$$

- Heating energy for slop sink

$$\frac{8.3 \times w \times 250 \left(\frac{120 + 130}{2} - 60 \right)}{0.95} = 1,419,737 \text{ BTU per year}$$

(NOTE: If used as booster for 95°F water, 546,052 BTU)

- Total annual energy use

$$4,368,421 + 1,419,737 = 5,788,158 \text{ BTU per year}$$

$$\frac{\$14.56 \times 5,788,158}{1,000,000} = \$84.28 \text{ per year}$$

Second Alternate - One-gallon Tank Heater

- Heating energy for lavatories

$$\frac{8.3 \times 2 \times 25 \times 250 \times (95 - 60)}{0.95} = 1,310,526 \text{ BTU per year}$$

- Heating energy for slop sink

$$\frac{8.3 \times 10 \times 250 \times (120 - 60)}{0.95} = 1,310,526 \text{ BTU per year}$$

- Standby losses (from example 2, fifth alternate)

$$352,932 \text{ BTU per year}$$

- Total annual energy use

$$3,822,368 + 1,310,526 + 352,932 = 5,485,826 \text{ BTU per year}$$

$$\frac{\$14.56 \times 5,485,826}{1,000,000} = \$79.87 \text{ per year}$$

Third Alternate - One-Half Gallon Tank Heater

- Heating energy for each lavatory

$$E = \frac{8.3 \times (12-1/2 \times 250) (95 - 60)}{0.95} = 955,592$$

$$4 \text{ basins} = 3,822,368 \text{ BTU per year}$$

- Standby loss (from example 2, fourth alternate)

$$1,534,485 \text{ BTU per year}$$

- Slop sink (from first alternate)

1,419,737 BTU per year

- Total annual energy use

$3,822,368 + 1,534,485 + 1,419,737 = 6,776,590$ BTU per year

$\frac{\$14.56 \times 6,776,590}{1,000,000} = \98.67 per year

Energy use and costs are summarized in Table A-7 for all the alternatives possible under this case. Table A-8 summarizes the inputs for life cycle cost analysis which is displayed as Table A-9.

TABLE A-7
SUMMARY OF WATER HEATING ALTERNATIVES

<u>Lavatory Basin Heater</u>	<u>Slop Sink Heater</u>	<u>Water Use Energy Demand BTU/Year</u>		<u>Stand-By Loss BTU/Year</u>		<u>Total Annual Energy Demand</u>	<u>Total Annual Energy Cost</u>
		<u>Basins</u>	<u>Slop Sink</u>	<u>Basins</u>	<u>Slop Sink</u>		
Storage (120)	Storage	8,300,000	1,660,000	7,008,000		16,968,000	\$ 62.27
Storage (95)	Instant Boost	4,841,667	546,052	5,840,000		11,227,719	47.15
Instant	Instant	4,368,421	1,419,737	-	-	5,788,158	84.28
Instant	1 Gal. Tank	4,368,421	1,310,526	-	352,932	6,031,879	87.82
1 Gal. Tank	1 Gal. Tank	3,822,368	1,310,526	-	352,932	5,485,826	79.87
1 Gal. Tank	Instant	3,822,368	1,419,737	-	-	5,356,853	78.00
1/4 Gal. Tank	Instant	3,822,368	1,419,737	1,534,485	-	6,776,590	98.67
1/4 Gal. Tank	1 Gal. Tank	3,822,368	1,310,526	1,534,485	352,932	7,020,311	102.22

TABLE A-8

SUMMARY OF LIFE CYCLE COSTING INPUTS

Installation Configuration	Storage	Storage	Instant	Instant	1 Gal Tank	1 Gal Tank	1 Gal Tank	1 Gal Tank
Basin Heaters	Storage	Instant	Instant	1 Gal Tank	1 Gal Tank	Instant	Instant	1 Gal Tank
Purchase Storage Heater	\$190.00	\$190.00	-	-	-	-	-	-
Purchase 1 - 9 kw Inst.	-	120.00	\$120.00	-	-	\$120.00	\$120.00	-
Purchase 4 - 3 kw Inst.	-	-	480.00	\$480.00	-	-	-	-
Purchase 3 - 1 Gal Heat.	-	-	-	-	\$456.00	-	-	-
Purchase 2 - 1 Gal Heat.	-	-	-	-	-	304.00	-	-
Purchase 1 - 1 Gal Heat.	-	-	-	152.00	-	-	-	\$152.00
Purchase 4 - 1/4 Gal Heat.	-	-	-	-	-	-	364.00	364.00
110V Elec. to	-	-	-	-	-	-	-	-
5 appliances	-	-	-	150.00	-	-	-	160.00
4 appliances	-	-	128.00	-	-	-	128.00	-
3 appliances	-	-	-	-	96.00	-	-	-
2 appliances	-	-	-	-	-	64.00	-	-
220V Elec. to	-	-	-	-	-	-	-	-
1 appliance	-	50.00	50.00	-	-	50.00	50.00	-
Plumbing Connection	-	67.00	335.00	342.00	222.00	201.00	335.00	342.00
Install copper pipe	-	-	-	-	-	-	-	-
from heater to basins	439.00	439.00	-	-	-	-	-	-
Total Installed Cost	629.00	866.00	1113.00	1134.00	774.00	739.00	997.00	1018.00
Annual Energy Cost	-	-	-	-	-	-	-	-
In 1980	\$ 62.27	\$ 47.16	\$ 84.28	\$ 87.82	\$ 79.87	\$ 78.00	\$ 98.67	\$102.22

TABLE A-9
LIFE CYCLE COST ANALYSIS
ASSUME DOE REGION I

Installation Configuration Basin Heaters Slop Sink Heaters	Storage Storage	Storage Instant	Instant Instant	Instant 1 Gal Tank	1 Gal Tank 1 Gal Tank	1 Gal Tank Instant	1/2 Gal Tank Instant	1/2 Gal Tank 1 Gal Tank
A. Purchase Cost and Labor	\$ 439.00	\$ 866.00	\$1113.00	\$1134.00	\$ 774.00	\$ 739.00	\$ 997.00	\$ 1018.00
B. Annual Energy Cost								
Gas	62.27	39.20						
Electric	-	7.96	84.28	87.82	79.87	78.00	98.67	102.22
C. Present Worth Factor 10 Yrs.								
Gas	6.903	6.903						
Electric	-	6.459	6.459	6.459	6.459	6.459	6.459	6.459
D. Life Cycle Energy Cost B X C								
Gas	429.84	270.60						
Electric		51.41	544.36	567.23	515.88	503.80	637.31	660.24
E. Total Life Cycle Cost A + D	868.84	1188.01	1657.36	1701.23	1289.88	1242.80	1634.31	1678.24

COMMENTARY:

A single conventional storage heater is the clear financial choice here both because of lowest installed cost including pipe and because of the gas-electric rate differences. Note, however, from the previous table that columns 3, 5 and 6 yield about 1/3 the annual energy use of the storage heater.